
Human Ecology

Content:

Adaptations to extreme environments

- ▼ The effects of extremes of environmental temperature and of life at high altitude.

Extremes of temperature

- ▼ Normal body temperature and diurnal variation.
- ▼ The structural, physiological and behavioural mechanisms of temperature regulation, including the structure and roles of the skin, and the roles of thermoreceptors and the hypothalamus.
- ▼ The causes and effects of heat stress, including salt loss, heat cramp, moderate and severe dehydration.
- ▼ The differences between acclimatisation in a visitor and adaptation in a native.
- ▼ The causes and effects of cold stress, including cold injury, trench foot and frostbite, wind chill and exposure leading to hypothermia.

High altitude

- ▼ The environmental conditions in high mountains, including low atmospheric pressure, low temperature, low humidity, high winds and increased solar radiation.
- ▼ The physiological effects of high altitude including hypoxia, hyperventilation, changes in lung volume and pulmonary diffusing capacity, increased red cells and haemoglobin concentration, initial increase in cardiac output.
- ▼ The effects of high altitude stress, including the general symptoms of mountain sickness, increased secretion of antidiuretic hormone, redistribution of body fluids, and impairment of mental reactions.
- ▼ The differences between acclimatisation in a visitor and adaptation in a native.

Introduction

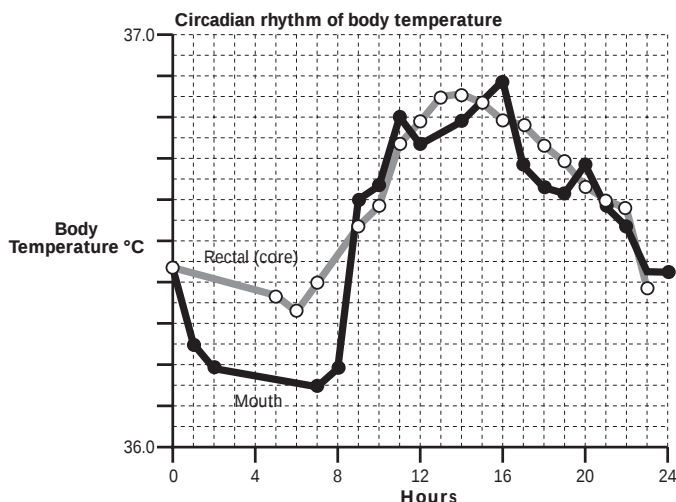
Archaeological and genetic evidence strongly suggest that modern humans, *Homo sapiens*, and their ancestors, evolved in sub-Saharan Africa. The environmental conditions in the savanna regions where humans evolved included high daytime temperatures (exceeding 40°C), cool nights (but with temperatures always above freezing), moderately low humidities and relatively high atmospheric pressure of oxygen. In view of this it is not surprising that in biological (physiological) terms humans are exceptionally well adapted to hot conditions yet rather poorly adapted to cold conditions and the conditions experienced at high altitude. In spite of this, behavioural or cultural adaptations of humans have allowed the species to exploit almost every natural habitat of the world: a larger range than any other single species.

Normal body temperature and diurnal variation

Humans, in common with birds and other mammals are **endothermic**, in other words, they generate their own heat energy and are capable of maintaining a relatively constant body temperature despite wide fluctuations in their surroundings. This allows the biochemical reactions in body cells to proceed at optimum rates, unaffected by temperature changes.

Changes in body temperature do occur but only between narrow limits around the normal 37°C. Daily (**diurnal**) fluctuations in body temperature coincide with periods of rest and activity, the temperature rising during the day when a person is active, and falling at night whilst asleep, and varying from around 36 to 37°C. Daily rhythms like this are called **circadian** rhythms. In menstruating women, a monthly rhythm occurs whereby the average body temperature rises during the last half of the cycle.

Whilst it is possible for the body to survive a 10°C drop in temperature, it can be fatal for the temperature to rise by as little as 4°C. At high temperatures, nerve function is impaired and some enzymes are denatured, stopping vital reactions in cells. It is important, however, to distinguish between the '**core**' temperature of the body, to which these figures relate and the '**shell**' of the body which comprises the skin and underlying tissues. The shell temperature may vary much more with the surroundings because it is not perfectly insulated.



Heat transfer between the body and the environment can occur by any of the following mechanisms:

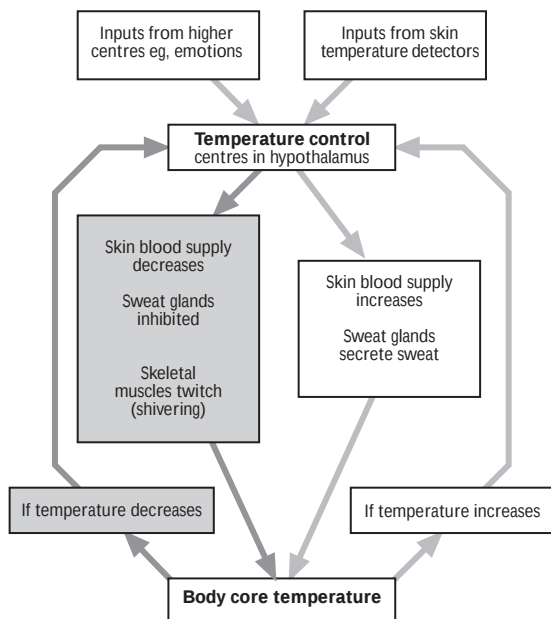
Radiation: For example heat is lost by radiation to the air from the skin surface when the external temperature is less than that of the skin.

Conduction: Direct transfer of heat from warm to cold materials, including air and water. For example heat may be gained by the skin from the water in a hot bath. Heat loss to the air layer surrounding the skin by conduction is increased by air movements such as those created by **convection**. (convection is the process whereby warm air rises to be replaced by colder air moving in to replace it).

Evaporation: A large quantity of energy is required to change water from a liquid to a gas (2.42kJ for every gram of water). This energy (latent heat of vaporisation) is absorbed from the surface when water evaporates. The skin and respiratory surfaces therefore cool whenever water evaporates from them.

The structural, physiological and behavioural mechanisms of temperature regulation, including the structure and role of the skin, and the roles of thermoreceptors and the hypothalamus.

Changes in body temperature are detected both in the skin and the internal body organs by receptors (**thermoreceptors**) linked to the nervous system. Information is processed by a part of the brain called the **hypothalamus** which directs corrective responses, e.g. sweating, shivering, via nerves to the various **effectors** (sweat glands, arterial muscle etc). The hypothalamus can be thought of as the body's thermostat regulator. It controls the involuntary physiological mechanisms by which the body core is maintained at a constant temperature. It should not be forgotten that the conscious parts of the brain (cerebral hemispheres) are also alerted by the thermoreceptors to fluctuations in core temperature and by skin receptors to the external conditions. By this means a person can take voluntary corrective measures, for example, a change of clothing, position or activity. Such responses are called **behavioural mechanisms** of temperature control.



There are two sets of sensors or receptors in the body which can detect temperature changes both of which are modified nerve endings and hence part of the nervous system. They are known as thermoreceptors.

Firstly there are thermoreceptors in the hypothalamus of the brain which sense the temperature of blood passing through it (the core temperature) and detect deviations from this temperature, however slight. To make the process more sensitive the hypothalamus has separate heat and cold receptors located in the heat loss and heat gain centres. Stimulation of sensors in both the hypothalamus and skin generate signals in the nervous system which then stimulate appropriate effectors (see below). When cold receptors have been stimulated, effectors are stimulated which increase heat gain and decrease heat loss. When heat receptors have been stimulated, effectors which allow increased heat loss or decreased heat gain are stimulated.

The second set of thermoreceptors, also including both heat and cold receptors, are in the skin. These detect changes in the environmental temperature and send nerve impulses to the hypothalamus which then processes the information and sends an appropriate signals to effectors. They also send nerve impulses to the cerebral hemispheres of the brain allowing the person to be conscious of being warm or cold. This can trigger some of the behavioural responses discussed below.

Physiological mechanisms of temperature control are directed by the hypothalamus and are not under conscious control. The effector organ for these control mechanisms is the skin.

Whilst the skin has a number of roles in the body, many of its structures are of vital importance in temperature regulation. In outline these include:

- ▼ **Sweat glands** connected to sweat pores produce sweat and secrete it onto the skin surface. As sweat evaporates it removes heat from the skin (the latent heat of vaporisation).
- ▼ **Blood capillaries** form a dense network throughout the dermis. The flow of blood through the capillaries is controlled by arterio-venous shunts. When blood is diverted to surface capillaries there is an increase in heat loss by radiation, conduction and convection.
- ▼ **Thermoreceptors (hot and cold)** are nerve endings which act as temperature sensors, detecting changes in air temperature and transmitting this information to the hypothalamus.
- ▼ **Adipose (fat) tissue** lying below the dermis provides thermal insulation, preventing excess heat loss from the body.
- ▼ **Sebaceous glands** produce an oily secretion (sebum) which waterproofs the skin and hair and reduces water loss from skin cells.
- ▼ **Erector pili muscles** contract to raise the hairs at the base, in order to trap a layer of still air next to the skin and reduce heat loss; however with the reduction of body hair and the adoption of clothing this function is redundant in humans. The contracted erector pili muscles produce the familiar 'goose-pimples' seen on the skin when cold or emotionally stimulated.

Heat Gain

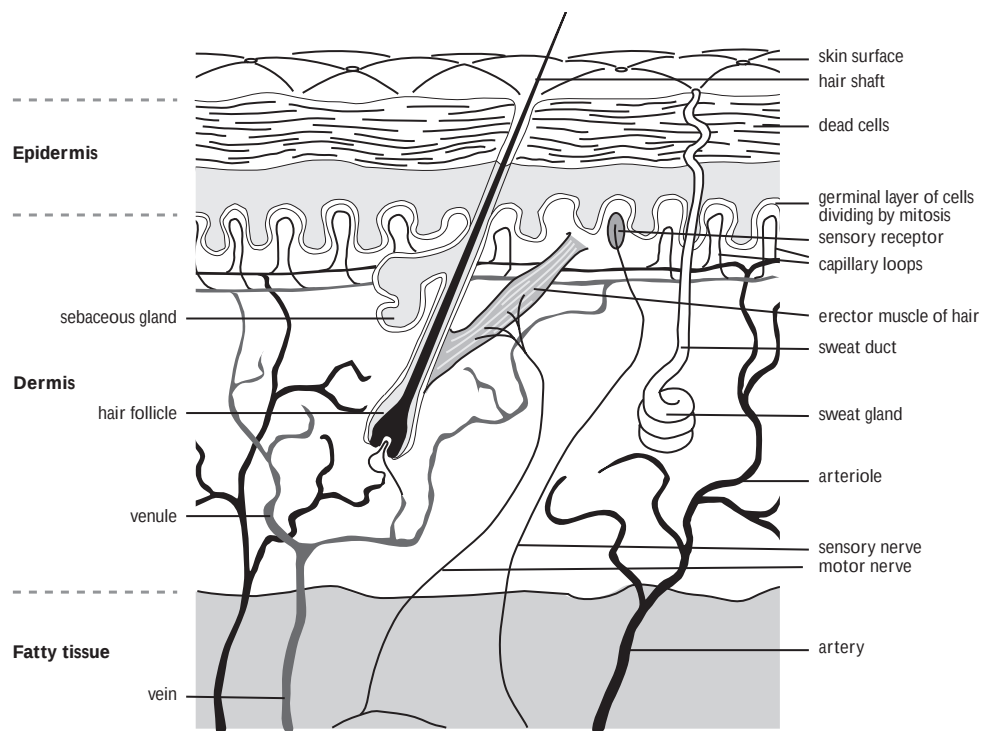
Heat may be absorbed from the surroundings, for example by taking a hot bath or sitting in the sun, but it can only be generated in the body by respiration and so the most important means of increasing heat production is by exercise which raises the rate of respiration in the skeletal muscles. Heat from respiring tissues and organs is circulated around the body, and from the core to the shell, by means of the circulating blood.

In cold conditions, the **shivering** reflex may be triggered by the hypothalamus. This is an involuntary response by which skeletal muscles are stimulated to contract rhythmically, generating heat in the process.

Heat loss

The human body loses heat to the environment by the physical processes of conduction, convection, radiation and evaporation. Whilst the first three depend on the environment being colder than the person, evaporation does not. This is therefore the only means of heat loss available when the air temperature exceeds 37°C.

The most important regulatory mechanisms for temperature control are **sweating** and **vasodilation**, both of which allow the body to lose excess heat generated by exercise or absorbed from warm surroundings.



In general, heat is generated in the core and transferred to the shell by arterioles which supply the capillary beds of the skin and underlying tissues. The volume of blood to the shell, and consequently the amount of heat transfer, can be regulated by means of the involuntary (smooth) muscles which line the walls of these arterioles. **Vasoconstriction** is a narrowing of the arterioles by contraction of the muscular wall, **vasodilation** is a widening of the arterioles by relaxation of the muscular wall. When the body needs to lose heat, more blood is shunted to the shell by vasodilation. The increased blood supply causes the skin to change to a red colour and heat is lost by radiation from the surface.

Sweating is a very effective way of losing heat provided that the fluid evaporates directly from the skin surface and does not run away or soak into clothing. Theoretically the evaporation of 1 litre of sweat can remove 2500kJ of heat from the body, and sweat may be lost at the rate of several litres per hour, but even during moderate exercise or on a warm humid day the loss of fluid may be potentially harmful. Sweat is a dilute solution containing salt, so sweating can cause both dehydration and an electrolyte imbalance if the water and salt are not replaced by appropriate nutritional intake.

The choice of clothing for different activities and conditions is very important. Clothing acts as an insulating layer between the skin and the external environment, trapping a layer of air. The more air layers, the more insulation. It is important that clothing should be loose in order to preserve the air layers and to allow air movement. Light colours reflect radiant energy from the sun whilst dark colours absorb radiant energy. Loose fitting light coloured clothes are best for hot climates as they also allow effective sweating to occur at the skin surface.

THE CAUSES AND EFFECTS OF HEAT STRESS, INCLUDING SALT LOSS, HEAT CRAMP, MODERATE AND SEVERE DEHYDRATION

The causes and effects of heat stress.

Between 25°C and 30°C body temperature is regulated entirely by means of changes in blood flow from core to shell. This range is called the **thermoneutral zone**. Below 25°C, the body must increase its heat production by muscular activity. Above 30°C, sweating occurs. If the external temperature rises above the normal body temperature (37°C), then the body will absorb excess heat from its surroundings unless it is completely insulated.

Whilst the body is well adapted to deal with high temperatures, prolonged exposure to heat can place a stress on the body, preventing it from functioning in an optimum fashion. Basically **heat stress** occurs when the rate of heat gain by the body (by transfer from the environment and from metabolic reactions) exceeds heat loss by sweating and other means.

The rate of heat loss by evaporation is affected greatly by the relative humidity. Most people can tolerate temperatures of 40°C without discomfort if the air is dry, but will suffer from heat stress at this temperature if the relative humidity rises. **Heat stress** is related to loss of fluid through sweating. This is a common problem in people undertaking hard physical work in tropical regions.

In its mildest form heat stress is referred to as **heat exhaustion** and characterised by a drop in blood pressure (hypotension) brought on by a loss of blood fluid volume and the shunting of blood to the shell. If the conditions causing heat stress are prolonged, then the temperature control mechanisms may break down altogether resulting in delirium and unconsciousness. This is called **heat stroke** and can quickly lead to death if the conditions are not reversed.

Salt loss and heat cramp

As salt is lost from the body in sweat, the concentration of sodium in the extracellular fluid decreases. This can lead to the development of painful muscle cramps, which are related to the fact that sodium plays a major role in conduction of nerve impulses and muscle contraction. Muscle cramps occur in the same way whether there has been a net loss of both water and salt from the body, or simply a net loss of just salt with an adequate supply of pure water.

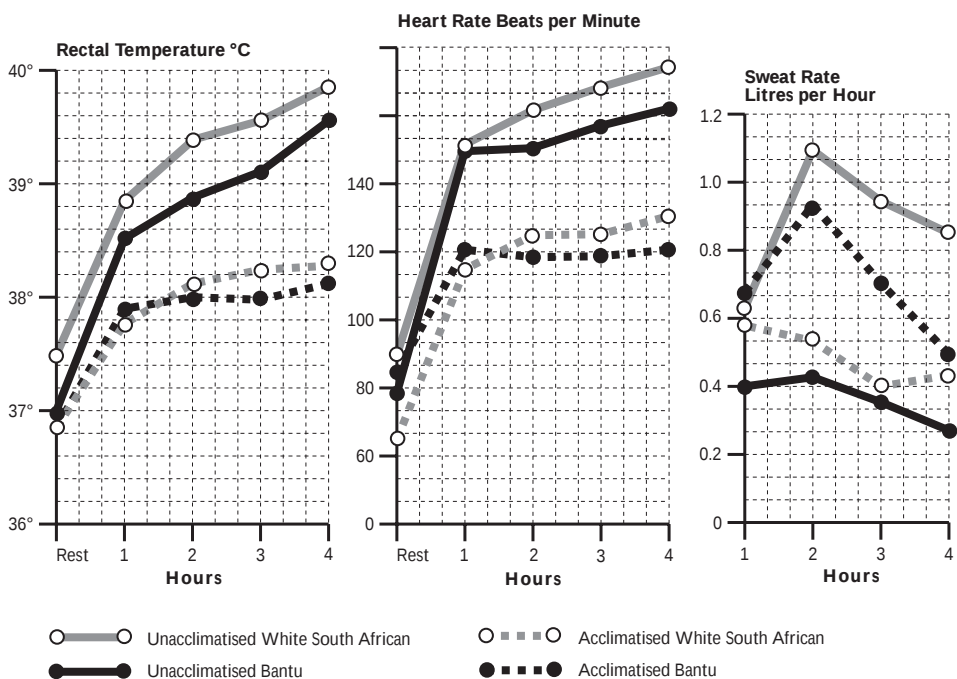
The effects of water loss (dehydration)

Sometimes known as heat exhaustion, common symptoms of this are giddiness, fatigue, and weakness. In more severe cases it can lead to hypotension (low blood pressure brought about by the increased blood flow to skin and reduce blood volume through water loss) and to an increase of body temperature as the rate of sweating cannot meet the demand for heat loss. If this progresses, serious dehydration and delirium, loss of consciousness and even death may follow. This is often experienced by troops who undertake heavy exercise in hot climates without being acclimatised. (It should be noted that as dehydration progresses individuals become less aware of the sensation of heat and will not take measures to avoid heat gain, aid heat loss or rehydrate themselves.) It is generally said that a loss of more than 10% of total body water will result in death.

The differences between acclimatisation by a native and adaptation in a visitor

Acclimatisation is the process whereby individuals adapt physiologically to environmental conditions different to those they are used to. Thermal acclimatisation (acclimatisation to heat) has been well studied. When an individual from a colder region moves into a hotter region he/she will spend 10-20 days acclimatising to the heat. Within this time a number of physiological changes occur which will allow the person to tolerate heat to a similar extent to a native person. Acclimatisation will produce the following changes:

- ▼ Decreased core temperature
- ▼ Decreased resting heart rate
- ▼ Increased rate of sweating and earlier onset of sweating
- ▼ Decreased salt loss in sweat



It should be noted that the extent of acclimatisation depends on the external temperature and the degree of activity. Thus to be fully acclimatised to manual work at 40°C a person must perform manual work at 40°C. Resting at 40°C or working at 35°C will not produce the full acclimatisation response. Acclimatisation to heat will be rapidly lost if the hot conditions are not experienced on a regular basis, but it is thought that it can be regained more rapidly on second exposure.

There is some argument as to whether non-native people can achieve the same tolerance of heat as those native to hot regions. Some studies claim that individuals who have been brought up in hot environments will have a greater number of active sweat glands, than those brought up in colder climates, and therefore have a slight advantage in heat loss by sweating. Differences in body size and shape and the amount of body fat will also play a role in heat tolerance. The large surface area to volume ratio (caused by long limbs) and the low body fat of native Africans may help to increase heat loss. Differences in physical fitness are also important.

The causes and effects of cold stress, including cold injury, trench foot and frostbite, wind chill and exposure leading to hypothermia.

As discussed above, humans are essentially a tropical species who could not tolerate most habitats outside the tropics without their extensive behavioural mechanisms to allow heat gain and prevent heat loss. Physiologically and anatomically humans are not well adapted to cold temperatures, and will suffer from a range of cold related injuries on exposure to prolonged cold temperatures. Cold stress occurs when the rate of heat loss exceeds the rate of heat gain by metabolic processes and behavioural means.

Cold injury, frostbite and trenchfoot

During prolonged exposure to extreme cold, physical injury to tissues may occur. This is generally limited to the skin and surface tissues of the extremities (hands and feet) where blood flow is reduced owing to the body's need to maintain a constant core temperature, and skin temperature may be close to environmental temperature. Some parts of face may also be affected since it is more likely to be directly exposed to the outside air.

Frostbite is defined as the formation of ice crystals in the skin and surface tissues (and more rarely muscle and bone) owing to a temperature of less than -3°C in that region. For this to occur, the outside temperature must usually be at least -6°C . Frostbite usually affects the fingers and toes, and because the individual has often lost feeling in the extremities he or she may not notice its development. Since frostbite kills the affected tissue this will eventually blister, turn black and be lost. Any remaining tissue is in danger of becoming infected, leading to gangrene, and perhaps death. Many mountaineers and arctic explorers have lost parts of their fingers and toes to frostbite either during expeditions or on return when parts have had to be surgically removed to prevent infection.

A related condition, known as **trenchfoot**, occurs in the extremities following prolonged exposure to cold (but not freezing) water. Rarely seen since the first world war, when it affected soldiers standing in wet trenches, this condition leads to deterioration of the tissues which may become infected.

Hypothermia

Hypothermia is defined as a fall in the core body temperature below 35°C . In mild hypothermia (the range from 32 – 35°C) the person feels intensely cold is alert, and attempts to warm up. If core temperature falls below 32°C (severe hypothermia) the person's mental state, including judgement of the conditions, and awareness of the cold is affected. S/he may go into a coma and death can follow, usually caused by severe irregularities of heart beat, brought on by changes in the respiratory rate of the contracting cardiac muscle.

Hypothermia occurs in three main situations:

- ▼ During prolonged exposure to extremely cold weather conditions, such as those encountered during high altitude mountaineering or expeditions in the Arctic and Antarctic. In these circumstances heat production cannot keep pace with heat loss. Hypothermia in these conditions is much more likely

if it is wet and windy. Wind has the effect of lowering the effective temperature and will rapidly evaporate water from wet clothes, so cooling the skin.

- ▼ Following long periods of immersion in water at 20°C or less, such as following an accident at sea.
- ▼ In the home environment of houses in cold climates with limited heating. Hypothermia is most common in inactive people (especially the elderly) and in those with a low level of body fat and a high surface area to volume ratio (especially babies). Some drugs may also contribute to the effect.

High Altitude

Over 25 million humans live at altitudes between 2500m-5500m on the mountain plateaus of Ethiopia, South America (the Andes) and Tibet (the Himalayas) in spite of several physical stresses associated with these environments. Of these the most severe stress for human populations is the reduced partial pressure of oxygen which effectively prevents permanent habitation above 5500m. (Although humans can of course survive for short periods of time, without extra oxygen, at altitudes above 8000m, as demonstrated by the ascent of Everest).

The relevant specific features of mountainous regions are:

- ▼ Low atmospheric pressure. At 5000m the atmospheric pressure is half that at sea level. This results in lower partial pressure of oxygen in the air and consequently in the alveoli and blood of humans. This affects the association and dissociation of haemoglobin and oxygen, the ability to transport oxygen around the body, and hence the ability to do work.
- ▼ Low temperatures for part or all of the year, particularly at night due to reduced cloud cover. Temperatures often fluctuate enormously over the year. For example, in the Himalayas day-time temperatures in summer may exceed 40°C whilst in winter they can drop to -40°C. A short growing season (4 months) limits food production.
- ▼ Low humidity. This is related to low atmospheric pressure as the air has a lower capacity to hold water vapour. Along with high wind speed this can increase the rate of water loss by evaporation leading to dehydration and heat stress. Low humidity also contributes to low rainfall with effects on plant growth and human nutrition.
- ▼ High wind speeds which increase the cold stress by adding a wind chill factor. This can increase the risk of hypothermia. High winds also increase evaporative water loss as discussed above.
- ▼ Increased solar radiation. Owing to the reduced air pressure and humidity UV rays penetrate the atmosphere more easily. This can lead to high temperatures at times of the year, and can lead to burning of the skin even when temperatures are low.

◆ CHECKPOINT SUMMARY

- ◆ Extremes of environmental temperature pose problems for the body's homeostatic mechanisms which strive to keep the core temperature at the optimum (normal) 37°C.
- ◆ Homeostasis is a dynamic equilibrium 'hunting' around the optimum
- ◆ In addition even under constant optimum external conditions when at rest, there are diurnal (daily) variations of body temperature as a result of diurnal rhythms of brain and hormonal activity.
- ◆ The skin has thermoreceptors and detects the heat gradient between it and the surroundings, and the hypothalamus of the brain measures the body temperature against the target of 37°C.
- ◆ Blood vessels in the skin are dilated or constricted according to the need to lose more or less heat over the skin by conduction, convection and radiation.
- ◆ Sweat glands secrete sweat onto the surface of the skin to lose heat by evaporation (latent heat of evaporation).
- ◆ Heat stress is caused the body attempting to regulate the core temperature in a hot climate without adequate supplies of water and electrolytes (salts).
- ◆ Sweating results in the loss of water leading to moderate or severe dehydration if not replaced, and the associated loss of salts can lead to heat cramps.
- ◆ Visitors to hot climates can acclimatise after a period as a result of an increase in efficiency of the heat regulating mechanisms.
- ◆ People native to the conditions are adapted genetically to low body fat, and large surface area to volume ratio.
- ◆ The body can withstand a greater drop of temperature than it can a rise, because with a drop in temperature metabolism slows so damaging processes are also slowed.
- ◆ Windchill and exposure lead to hypothermia and below a certain critical temperature the circulation to the extremities and the limbs is shut down in order to conserve the core temperature.
- ◆ The reduction in blood flow leads to cold injury, trench foot and frostbite.

The physiological effects of high altitude

Individuals at altitudes above about 2500m suffer from **hypoxia** (a condition where the oxygen content of the blood is too low to allow adequate aerobic respiration in tissues). The effects of hypoxia can be divided into acute hypoxia experienced within minutes or hours of entering a high altitude region and chronic hypoxia experienced by residents and long term visitors who have become acclimatised to high altitude regions.

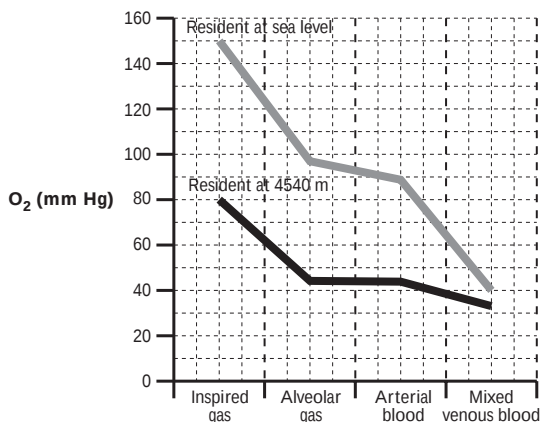
Hyperventilation and changes in lung volume

One of the earliest symptoms of hypoxia is an increase in the rate and depth of breathing (hyperventilation) brought about by a low partial pressure of oxygen in the alveoli of the lungs. This functions to allow more oxygen to enter the lungs. It should be noted that another effect of this is to increase the excretion of carbon dioxide from the alveoli. Low pp of CO_2 in the alveoli and blood causes a decrease of breathing rate. These opposing effects can lead to unpleasant cycles of fast and slow breathing in the first few days at altitude. Over time, however, the body achieves a stable, increased, respiratory minute volume (amount of air breathed per minute).

Pulmonary diffusing capacity

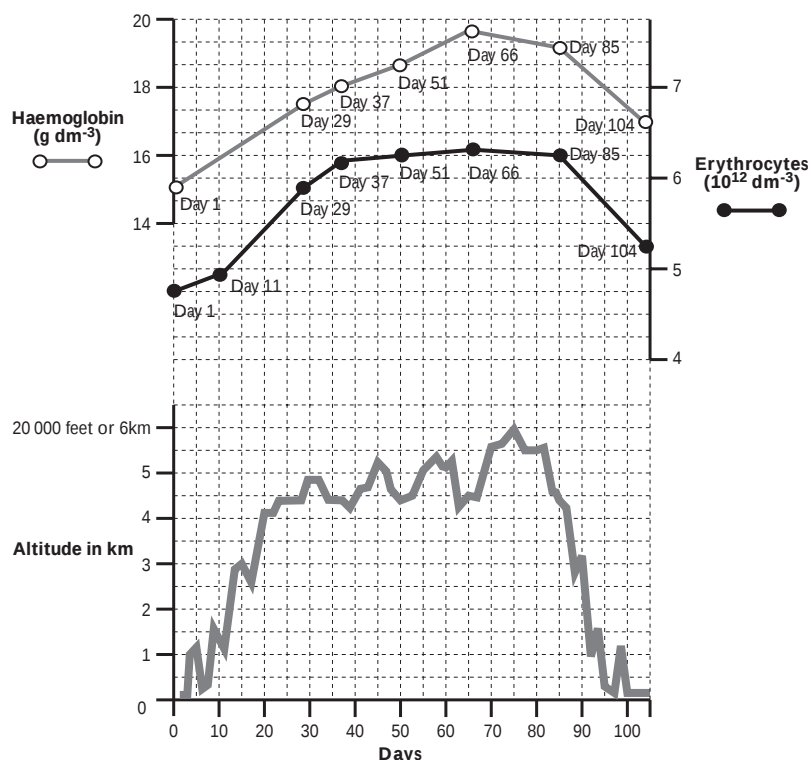
Hypoxia can sometimes lead to **pulmonary oedema** where the tissues surrounding the capillaries of the lungs (including the alveoli) become swollen with excess tissue fluid. This is thought to result from increased blood pressure which forces extra fluid out of capillaries at the arterial end and prevents it from moving back into the capillaries at the venous end. When fluid accumulates around the alveoli it increases the distance between air spaces and the blood, and hence reduces the diffusing capacity of oxygen into the blood and carbon dioxide out of the blood. This can lead to breathlessness.

Oxygen levels at different altitudes



Increased number and haemoglobin content of red blood cells

Low partial pressures of oxygen in the blood stimulate the release of the hormone erythropoetin from the kidney which increases the rate of production of red blood cells. Red blood cell numbers may almost double in extreme cases. The haemoglobin content of each RBC and therefore the total haemoglobin in the blood also increases, improving oxygen transport around the body. This effect, and the effect of increased density of capillary networks in the tissues is often exploited by endurance athletes who train at high altitudes for period of several weeks or months. On their return to sea level they will experience temporary improvements in aerobic performance.



Increased cardiac output

Acute hypoxia causes a rapid increase in heart rate and hence cardiac output (heart rate x stroke volume). This improves oxygen delivery to the tissues. Over prolonged periods at altitude, heart rate is gradually reduced to values close to normal at sea level. This may be due to the improved oxygen carrying capacity of the blood and increased density of capillary networks in tissues.

High altitude stress: mountain sickness and other effects of high altitude

Mountain sickness is a term used to describe signs and symptoms experienced by some people at altitudes above 3500m. These can include nausea (feeling sick), headaches, lethargy, dizziness, diarrhoea, and psychological disturbance. In severe cases acute pulmonary oedema and or cerebral oedema (accumulation of fluid in the tissues of the brain) can occur which may be fatal. The exact cause of mountain sickness is not clear but includes both hypoxia and dehydration. Individuals vary widely in their tendency to develop symptoms, and these variations are not related to physical fitness or health.

At altitude there tends to be an increase in the quantity of anti-diuretic hormone (ADH) secreted by the posterior pituitary gland in response to a reduction of water levels in the blood. ADH helps to conserve body water by allowing increased reabsorption of water in the kidney, and hence production of smaller volumes of concentrated urine. Water levels of the blood may be reduced at altitude for several reasons: firstly high wind speeds, dry air and sometimes intense solar radiation increase the rate of evaporation of sweat from the skin (and possibly from the lungs and mouth/nose as breathing rate increases) and secondly, water may be scarce and intake lower than necessary.

It is very important for the body to maintain a constant water level and hence volume of blood. If blood volume falls then blood pressure will fall and the exchange of materials between blood and tissue fluid (interstitial fluid) will be affected. To help to prevent this water may move from the intracellular compartments of the body (i.e. within cells) into the extracellular fluid (blood and tissue fluid).

Hypoxia can affect brain function in a number of ways even at moderate altitudes. Affects include poor judgement, slower reaction times, poor co-ordination, impairment of short term memory and learning skills. Severe hypoxia can cause permanent brain damage (as experienced in babies deprived of oxygen at birth) and in some mountaineers. It may also result in coma and death.

Acclimatisation and adaptation to high altitude

In contrast to the ease with which humans acclimatise to high temperatures, it is difficult to acclimatise to the chronic hypoxia of high altitudes. Visitors, even those who stay for months or years, never become as well adapted to the environment as natives. However, as described above, acclimatisation to altitude, does occur. Changes in respiratory volume, RBC number, and haemoglobin content of RBCs begin almost immediately and continue over weeks and months at altitude. Acclimatisation is often best achieved by gradual ascent to altitude. Therefore a person who climbs up to the high plateaus of the Himalayas or Andes is often spared the effects of acute mountain sickness whereas one who flies in to such a place could experience severe effects.

High altitude natives are thought to possess genetic and developmental adaptations to high altitude as well as the benefits of acclimatisation. One striking feature is a barrel shaped chest providing increased lung size and volume. Coupled with this, such individuals have very high values of $\text{VO}_2 \text{ max}$ (maximal value of oxygen uptake per kg of body mass per minute), a measure of the ability to do physical work. The $\text{VO}_2 \text{ max}$ of natives can never be equalled by non natives, even those who spend many years at altitude. It is interesting to note that whilst an acclimatised non-native individual has an improved $\text{VO}_2 \text{ max}$ when he returns to sea level, a native does not.

A further genetic adaptation of high altitude natives is a dark skin colour to reduce skin damage by the high levels of UV light.

◆ CHECKPOINT SUMMARY

- ◆ In high mountains there is low atmospheric pressure, low temperature, low humidity, high winds and increased solar radiation.
- ◆ The low atmospheric pressure means that there is a proportional drop in oxygen content leading to insufficient oxygen in the blood (hypoxia).
- ◆ The thinner air and lack of oxygen leads to hyperventilation, a decrease in lung volumes and in pulmonary diffusing capacity. Above 1600m maximum oxygen uptake decreases by about 10% for every 1000 m increase in altitude.
- ◆ There is an initial increase in cardiac output to increase the blood supply to the lungs and the tissues of the body.
- ◆ After a longer period increased secretion of the hormone EPO increases the number of red blood cells and haemoglobin concentration to compensate for the lower external oxygen levels.
- ◆ High altitude stress includes the general symptoms of mountain sickness, increased secretion of anti-diuretic hormone (ADH) and consequent retention of fluid, redistribution of body fluids and impairment of mental reactions.
- ◆ After a period visitors acclimatise as a result of the changes in the red blood count and efficiency of breathing, and those native to altitude are adapted permanently with high blood counts.